PHOSPHORUS FIXATION BY HORIZONS OF VARIOUS SOIL TYPES IN RELATION TO EASILY EXTRACTABLE IRON AND ALUMINUM

by

DALE SERVETUS ROMINE

B. S., Kansas State College of Agriculture
and Applied Science, 1934

A THESIS

submitted in partial fulfillment of the

requirements for the degree of

MASTER OF SCIENCE

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1938

KANSAS STATE COLLEGE LIBRARIES

Document
LD
2668
T4
1938
R62
c.2

TABLE OF CONTENTS

	Page
INTRODUCTION	2
REVIEW OF LITERATURE	4
DESCRIPTION OF SOIL PROFILES STUDIED	16
LOCATION OF SOIL PROFILES	24
ANALYTICAL METHODS	25
EXPERIMENTAL RESULTS	29
I. Phosphorus Absorption by the Original Soil	29
II. "Available" Phosphorus	32
III. Phosphorus Absorbed After Extraction	34
IV. R_2O_3 Extracted	39
DISCUSSION	48
SUMMARY	56
ACKNOWLEDGMENT	58
LITERATURE CITED	59

INTRODUCTION

The mechanism of phosphorus fixation has received much attention in soil research. Although many studies have partially revealed the nature of phosphate retention, exact knowledge of its mode of occurrence in natural soil is limited. It is known that phosphates, besides being occasionally present in small crystals of apatite in the sand fraction of soils and possibly also in the silt, are regular constituents of the clay fraction. Here the mode of combination of the phosphorus is relatively obscure.

Agriculturists are familiar with the fact that soluble phosphates in fertilizers become relatively insoluble when mixed with soils, and that losses by leaching are almost invariably negligible. This phenomenon whereby soluble phosphorus is removed from solution by soils is termed "fixation." Terms such as "absorption," "adsorption," and "reversion" are used to designate specific forms of fixation. Early workers attributed this fixation to a simple chemical reaction. It was believed that when a soluble phosphatic fertilizer was added to the soil the phosphate ion would combine with the bases present to form relatively insoluble compounds. There is evidence that this chemical combination does account for a variable fraction of the soils capacity to fix phosphorus. The remainder of the fixation, however, is generally attributed to much more complicated reactions. Since natural soils contain many substances capable of fixing phosphates it is obvious that the amount of phosphorus fixed and the mode of fixation by a particular soil will vary with the proportion of these substances present as constituents, and the intensity of the factors influencing their activities.

Considerable data are now available both from controlled laboratory studies and plant response studies which definitely establish the fact that soils vary rather greatly in their capacity to fix phosphates. Also the forms in which it is fixed vary in degrees of availability for plant growth from easily available to non-available. This situation, added to the fact that phosphorus is frequently one of the limiting nutrients in plant growth, immediately brings phosphorus fixation by soils into the realm of practical significance in soil fertility programs.

Many soils are deficient in available phosphorus even though the total supply of native phosphorus may be relatively high. Some soils have such high fixing capacity for phosphorus that plants may suffer from phosphorus deficiency even though some phosphorus has been supplied in the form of fertilizer. The fixing capacity of the soil is determined in large part by the nature of the soil, which in turn is an expression of the environmental factors under which it was developed. Other features such as organic matter content and the lime status of the soil are important factors determining fixing capacity.

In the work reported here an attempt was made to study the relative fixing capacity of several horizons of each of a number of soil types. A further attempt was made to determine what relationship, if any, exists between the easily extractable iron and aluminum and, (a) the easily extractable phosphorus, and (b) the phosphorus fixing capacity of the various horizons of several soil types.

REVIEW OF LITERATURE

A review of literature on the subject of phosphorus fixation and availability discloses several views which appear to be conflicting. It is erroneous, however, to compare or contrast findings of the various workers without first properly considering and evaluating the conditions under which the investigations were conducted. The literature review in this paper has been limited to studies of a related nature and of recent origin.

The role of soil composition and constituent activity, particularly of the clay fraction, in phosphorus fixation is decidedly great. Hester (17) has shown that if the basic residue of the soil is increased by aluminum the phosphate absorbing power becomes much greater. Heck (14) found that dark colored soils containing abundant organic matter were generally low-fixing soils. Reddish yellow or yellow soils have the highest fixing power. This color arises from the presence of monohydrate (and perhaps dihydrate) ferric oxide, which is highly reactive. Truog and Ford (41) state that yellow colored soils fix phosphorus more readily than do red colored soils because of a difference in the form of iron compounds in these soils. Hance (12) states that subsoils show higher fixing power than surface soils. He defines a high-fixing soil as one that allows the soluble phosphates to penetrate 2 or 3 inches, and a mild-fixing soil as one that allows penetration to a depth of 2 or 3 feet.

Gile (11), Hibbard (18), Scarseth and Tidmore (32), found that the fixing power of soil colloids varies inversely as the silica-sesquioxide ratio of the colloid. Giles (11) also states that the effect of a soil colloid on superphosphate seems to depend on several factors, namely, the degree to which the colloidal material is saturated with phosphoric acid; the SiO_2/R_2O_3 ratio of the colloid; the effect of the colloid on the hydrogen-ion concentration of the medium, and the content of organic matter. He believes the relative importance of the different factors to be in the order given, the first mentioned being most important. His investigation of subsoils indicates that a condition of low phosphoric acid saturation, and consequently a low phosphate availability is rather general for subsoils where the silica-sesquioxide ratio of the colloid is not above 2. It is not unreasonable to expect that the potential iron and aluminum surfaces capable of combining with the phosphate would show some correlation with the SiO_2/R_2O_3 ratio.

Hibbard (18) holds that the "fixation" of phosphate in soil, in order of decreasing importance, is most influenced by pH, Ca^{++}, and silica-sesquioxide ratio in the soil colloids.

Mattson (23) has shown that the soil colloid is composed of an acidoid-basoid complex. The greater the acidic residue, the greater the exchange capacity of the clay. Phosphorus combines with the basoid complex to reduce its strength and increase the acidoid strength indicating that the seat of the phosphate absorbing power of the soil is in the basoid constituent of the soil colloid. He infers that the characterization of the soil colloidal materials resides not in the SiO_2/R_2O_3 ratio, but in the ratio of the activities of the acidoid and basoid fractions.

On the basis of a statement by Joffe (19) that the hydrated oxides of iron and aluminum occur in soils as natural products of the laterization process, it might be expected that lateritic soils with their high content of hydrated oxides of iron and aluminum, should possess a high phosphorus fixing capacity. That this is true has been shown by several investigators, notably Craig (5) and Heck (14). By the same reasoning, soils of intermediate nature between laterites and podsols (lateritic) should also possess considerable capacity to fix phosphorus in relatively insoluble forms.

Phosphorus availability not only varies with the different forms in which it is fixed in the soil but apparently there are varying degrees of availability within the same form.

Truog (39) conducted a very thorough experiment in which it was shown that at least a portion of the phosphorus in precipitated ferric and aluminum phosphates is available to plants. Apparently then, forms very difficultly available to plants must be fixed in combination less available than ordinary precipitated ferric and aluminum phosphates. Heck (13) states that when active calcium and aluminum are low, phosphates are fixed largely by iron, and the resulting compound is generally less soluble than the corresponding aluminum compound. Toth (38) indicates that the retention of phosphates by soil colloids is the result of a series of reactions. A portion of the adsorbed phosphate displaces silica, another fraction reacts with the free iron oxide, and the remainder displaces hydroxyl groups from the uncombined basoid. He found that the removal of free iron oxide from soil colloids lessens the magnitude of phosphate adsorption.

Heck and Truog (15) found that phosphorus was fixed quite completely in acid soils as basic iron and aluminum phosphates and that liming made it more available.

Ford (10) reports that hematite (Fe_2O_3) did not appear to fix phosphates whereas goethite ($Fe_2O_3 \cdot H_2O$) fixed large amounts. X-ray analysis of the minerals before and after phosphate application indicated that a crystalline phosphate of very low solubility was formed by the combination. He concludes that phosphates fixed by calcium and magnesium are relatively the most available; that those fixed by goethite and bauxite are of very low solubility. These three forms of fixation summarized by Ford seem to be the most important types occurring in soils.

McGeorge and Breazeale (21) observed that iron and aluminum hydrogels fixed large amounts of phosphorus which was insoluble in water, but completely soluble in dilute HCl. The gels were amphoteric, giving up the phosphate at alkaline reactions. $CaCO_3$ added to either gel increased, while $(Na)_2CO_3$ reduced, fixation. This observation helps explain the greater availability of phosphorus in black alkali spots. They conclude that iron and aluminum as well as calcium may be involved in phosphate fixation in these calcareous soils.

Meyer (27) believes an iron compound to be responsible for the fixation of phosphates in southern soils. It exists in concretions and fixes phosphorus as a basic ferrous phosphate. In later work (27) he found that soils low in organic matter but high in sesquioxides may fix large quantities of soluble phosphates in difficultly available forms.

Many investigators believe that adsorption by soil colloids plays a major role in phosphorus fixation. Mattson (24) working with pure colloids of alumina silicates and kaolin, has shown that some soil colloids are amphoteric, among them the sesquioxides of iron and aluminum. These were able to adsorb phosphorus in acid solutions. In evaluating this investigation, the fact that pure colloids were used, must not be overlooked. Mattson (25) showed that the phosphate ion was absorbed to a considerable extent by a number of soil colloids. He noted that most absorption occurred when the silica:sesquioxide ratio was the smallest, these ratios varying from 0.55 to 3.32. Teakle (36) says that the evidence at hand does not permit the denial of the existence of colloidal adsorption, but that at best it can play only a minor role in most soils.

The role of hydrogen-ion concentration in phosphorus fixation has been investigated quite extensively. In alkaline solutions iron hydrolyzes, liberating PO_4 ions which combine with calcium, the hydrolyzed iron remaining insoluble. Hibbard (18) suggests that this occurs above pH 8. While soil colloids of iron and aluminum may fix PO_4 at pH values ranging from 3 to 8, there appears to be no lower limit of acidity in which the fixation takes place with iron and aluminum. Doughty (9) found iron phosphate to be least soluble at pH 4.0 and aluminum phosphate at pH 6.5 and inferred that when both are present a soil should possess high fixing powers over quite a wide range of reaction. Davis (6) found extensive fixation occurring at pH values as low as 0.25. Brown (3) found that he could obtain a far greater amount of available phosphorus at pH 7.9 than at any other reaction and explains this by the low solubility of iron and aluminum and the little free calcium at this reaction. Heck (14) quotes Gaarder's finding that calcium phosphate is least soluble at pH 6.5. It was found further that at pH 6.0 the solubility of calcium, iron, and aluminum phosphates was the same, and that in consequence each of these bases has an equal chance in competition for the applied phosphate. In such instances the nature of the reaction would be determined by the relative amounts of these bases present in an active form. At its point of lowest solubility, pH 6.5, calcium phosphate is only one third as soluble as either iron phosphate or aluminum phosphate. From pH 6.5 upward, calcium predominates in combining with soluble phosphates.

Pugh (30) states that calcium phosphate is insoluble within a pH range from neutral to strongly alkaline.

Bradfield, Scarseth and Steele (2) found that at pH values from 2.0 - 5.0 the retention of the phosphate is chiefly due to the gradual dissolution of iron and aluminum and their reprecipitation as phosphates. At pH 4.5 - 7.5

the phosphate seems to be fixed on the surface of the clay particles. At pH 6.0 - 10.0, if divalent cations are present, the phosphate will be fixed largely by the divalent cations.

Benne, Perkins, and King (1) show that Ca^{++} ions did not precipitate phosphorus from H_3PO_4 solution until the pH approached 5.5. Maximum precipitation or minimum solubility was not reached until the pH approached 7.5. Large excesses of $CaCl_2$ precipitated no phosphorus from solution until the pH was raised by NaOH.

Naftel (28) shows that calcium had practically no effect on the sorption of phosphates by colloids of low SiO_2/R_2O_3 ratio, but with colloids of high SiO_2/R_2O_3 ratio the phosphates sorbed were greatly increased by calcium. Teakle (35) removed calcium from the soil solution by the addition of ammonium oxalate and found that the amount of phosphate in solution was increased greatly.

McGeorge and Breazeale (22) believe that in addition to the formation of tri-calcium phosphate, the phosphates exist in calcareous soils in combination with larger amounts of calcium than exists in $Ca_3(PO_4)_2$ and suggest that a very insoluble basic carbonate-apatite may be formed, and that it seems quite probable that calcium plays an important part in fixation of phosphorus into unavailable forms in calcareous soils.

McGeorge, Buehrer and Breazeale (20) concluded that carbonic acid and pH are the key to the availability of phosphate in calcareous soils.

The apparent importance of hydrogen-ion concentration in phosphorus availability has lead to considerable investigation of the effect of liming and addition of various other bases on the solubility of phosphorus. Snider (34) found that the addition of lime to certain soils increased the solubility of the native phosphorus fixed. Cook (4) cites results which support the contention that an increase in base saturation of soils lowers the immediate availability of rock phosphate, but tends to keep native soil phosphates and those added as soluble salts in the form of calcium phosphate rather than the less available iron phosphates. Teakle (35) showed that with varying degrees of soil acidity different cations are responsible for the removal of phosphate from the soil solution.

Perkins, King and Benne (31) found that when phosphorus was applied as $CaH_4(PO_4)_2$ the iron and aluminum soils precipitated large amounts of phosphorus; the H, Mg, Ca soils, intermediate amounts; and the K and NH_4 soils small amounts.

Heck (16) cites evidence to show that the removal of exchangeable bases from soils caused more fixation in the difficultly available form than in soils containing exchangeable bases and that the increase was somewhat proportioned to the exchangeable bases removed. Davis (6) tentatively concluded that phosphate fixation in soils artificially depleted of replaceable bases which can precipitate phosphate is due to absorption of the phosphate by the soil minerals and the formation of equilibrium complexes. In many soils not so depleted this process nevertheless predominates.

Because of the apparent minor role that organic matter plays in the fixation of phosphorus in difficultly available form, literature dealing with the subject is relatively limited. Doughty (8) concludes that soil organic matter as such has only a minor role, if any, in the fixation of phosphorus in difficultly available form when soluble phosphate fertilizers are applied to the soil. Natural and synthetic humus did not fix phosphorus. Odyusky (29) found organic phosphorus occurred in large amounts in the surface horizon, but below this the quantities of organic phosphorus diminished to very small amounts in the B_2 and C horizons. Easily soluble phosphorus was found to be present in much smaller quantities in the B and C horizons than in the A. The gray profiles showed a small proportion of difficultly soluble phosphorus in the A_0, much greater proportion in the A_1, A_2 and upper B_1 horizons, and small proportions below the upper B_1 horizon.

Anion exchange is considered by some investigators to be a possible factor in phosphorus fixation. Scarseth (33) observed that the attractive force of the phosphate anions was inversely proportional to the concentration of the hydroxyl anions, thus the increase of the phosphate ions in solution with the increase of pH values may be looked upon as an anion exchange phenomenon. Thomas (37) believes that the clay molecule contains a basic OH group replaceable by acid radicals such as PO_4, and that organic matter, especially soluble organic matter increases the solubility and penetrating power of soil phosphates.

de Vries and Hetterschy (7) found drainage from certain marsh soils of Holland contains 5 to 20 p.p.m. P_2O_5, indicating that important amounts may be lost therein. As the soil water is acid, pH 4.4, and is brown, the P_2O_5 is probably associated with humus. Leaching of fertilizer P_2O_5 into lower horizons has been proved to occur with these soils.

The concensus of opinion of these workers seems to be that in acid soils hydrated oxides of iron and aluminum are the chief causes of phosphorus fixation, and as a result of the relative insolubility of these phosphates the acid soils are likely to be low in soluble phosphorus though they may be high in total phosphorus content. The opinion seems to prevail that in neutral or slightly alkaline soils the phosphorus will combine with calcium and magnesium and thus be more soluble and more available than in strongly acid soils. Most of the investigators believe that pH value and degree of saturation of the soil with PO_4 are important factors in phosphorus fixation in all soils.

DESCRIPTION OF SOIL PROFILES STUDIED

Since leached soils are comparatively high fixers of phosphorus, it was deemed advisable to confine this study primarily to relatively leached soils. Fifteen soils of similar surface texture comprising fourteen different soil types and three duplications, were studied. A brief description of each follows, and the description is confined, primarily, to inherent characteristics which might be expected to influence phosphorus fixation:

The Cherokee silt loam, locally called "ashy land" has developed in the more nearly level areas of the country. The profile characteristics are very distinct. The lack of relief, together with the heavy claypan subsoil, renders drainage poor. The physical condition is generally poor. The surface soil, to a depth ranging from 7 to 18 inches, is grayish-brown or dark-gray silt loam of porous structure. The lower part of the surface layer, or that part just above the claypan, has been severely leached of available plant nutrients, and after plowing gives the field a light-gray appearance. This soil is almost white when dry and contains many small rounded ferruginous concretions. The claypan begins abruptly at a depth of about 14 inches. It is drab or grayish-brown, heavy compact clay, mottled with reddish-brown and yellow stains. With increasing depth the subsoil becomes lighter in color and texture and, at a depth of about 40 inches, changes to yellowish-gray shaly silty clay. The soil is very acid. The Cherokee silt loam was duplicated in this study; one sample was taken in Labette County 2 miles north of Parsons, and a second was taken in Cherokee County 2½ miles north of Hallowell.

The soils of the Crete series owe their origin to the weathering of loessial material. The surface soil consists of a brownish-gray to dark grayish-brown silt loam containing a very small amount of very fine sand and a high content of organic matter. The subsoil is usually made up of two distinct layers, the upper of which is a grayish-brown to reddish-brown compact silty clay loam, becoming lighter in color and texture with increasing depth. The soil is usually well supplied with lime throughout, while the deep subsoil frequently contains white lime concretions.

The Derby silt loam consists of a grayish-brown to brownish-gray silt loam, underlain at about 12 inches by a reddish-yellow to yellowish-red, friable, light silty clay loam, which becomes lighter colored and more friable with depth. The organic content of the soil is low. In some places adjacent to heavier soils the subsoil is not as friable in the upper section, and is slightly mottled yellowish brown and reddish brown. From its almost continuous occurrence, its position just above the bluffs along the Kansas River, and its uniform material, it would appear that this soil is of wind-blown origin and that the materials have been brought from the river bottom soils. It is subject to erosion on the steeper slopes.

The Hays silt loam was developed on residual material from limestone. It has a dark brown to very dark brown surface soil which is characterized by a rather pronounced degree of granulation. The subsoil is moderately heavy to heavy, although it is a relatively unleached soil. The structural development of the subsoil makes it permeable and allows ready movement of water and penetration of roots. A lime zone is encountered in the subsoil, usually below 30 inches depth, although much shallower on slopes. Free iron does not appear in the profile.

The Idana silt loam is derived from calcareous shales and limestone, and the surface soils test only slightly acid. The 9 to 12 inch top-soil is dark grayish-brown silt loam. It is underlain by a 5 inch transitional layer merging from silty clay loam into silty clay, and this in turn, is underlain by grayish-brown clay at a depth of 15 or 17 inches. Olive-gray clay is present in most places at a depth ranging from 32 to 36 inches. A few of the more nearly level areas are underlain by a somewhat heavier subsoil, but not a claypan.

The surface soil of the Jewell silt loam consists of dark grayish-brown to medium grayish-brown smooth silt loam carrying a relatively large amount of organic matter and extending to a depth of 10 to 12 inches. The subsoil is made up of two or more layers. The upper one, extending from twelve to twenty inches, consists of dark grayish-brown silty clay or silty clay loam. Below this lies a tough, compact layer of silty clay, varying in color from gray to dark brown. When wet this is very sticky and plastic, and on drying becomes brittle and impervious like hardpan. At a depth of twenty or thirty inches the compact layer grades into light gray or mottled silt loam or silty clay loam.

The surface of the Keith silt loam profile is brown to dark brown in color. It has developed a granular structure, but to less extent than the Hays soils. The subsoil is more compact than the surface soil, but there is little difference in texture. The darkening of the surface soil by the accumulation of organic matter extends to only shallow depth. A lime zone occurs within about 20-24 inches of the surface. It is derived from wind deposits. No free iron is to be seen in the profile. Two different profiles of this soil type are included in this study but only the phosphorus absorption by the original soil and pH values were determined.

The Knox silt loam consists of a light grayish-brown or buff-colored, smooth silt loam grading at about 12 inches into an open, friable silt loam. The lower subsoil is buff to light brownish-yellow and in places contains rusty-brown iron stains. The surface soil is low in organic matter. There is little difference in the material either in color, texture or structure to a depth of 36 inches. It is derived from loessial material.

Labette silt loam has developed from parent material residual from gypsiferous shales and limestone. The surface soil, to a depth of about 8 inches, is dark grayish-brown porous silt loam, the shade of color depending on the content of organic matter. The lower part of the surface soil is somewhat lighter in color, that is, reddish-brown, and it contains numerous iron pellets, or concretions. In plowed fields the surface soil is reddish-brown when dry and almost black when wet. There is no distinct line of demarcation between the surface soil and subsoil, but the subsoil begins at a depth of about 14 inches. It is dark reddish-brown, mottled and splotched with gray, yellow, and rust-brown stains, and with increasing depth it becomes lighter in color. The lower part of the subsoil is high in iron.

The Marshall silt loam is described as a dark-colored upland soil with a friable subsoil. The surface soil consists of very dark brown porous silt loam which appears black when wet, to a depth ranging from 12 to 16 inches, and it is underlain by a lighter brown transitional layer which extends to a depth of 20 or 24 inches. The color gradually becomes lighter brown with depth, owing to the gradual decrease in the organic matter content. The subsoil is light brown, ranging from heavy silt loam to silty clay loam, but is rather friable and nowhere approaches a claypan. The Marshall silt loam is slightly acid, the surface soil being the most acid.

Neosho silt loam is similar to Cherokee silt loam. It occurs along the terraces or second bottoms of the main streams in south-eastern Kansas. As in the Cherokee soil, the surface soil is low in organic matter. The physical condition of the soil is poor, and the material is strongly acid throughout. It has a less heavy claypan subsoil than the Cherokee silt loam.

The Shelby series is derived from glacial till, and consists of a dark-brown silt loam, 12 inches deep, underlain by a yellowish-brown, moderately friable silty clay loam, passing at 24 to 27 inches, into a mottled yellowish-brown and grayish-brown silty clay loam. The surface soil is moderately high in organic matter. The subsoil contains a small quantity of glacial grit, but not as much as is usually found in the associated Shelby loam. The surface is gently rolling, and the drainage is good.

Summit silt loam has developed from the weathering of limestone and shale. The surface soil is a very dark brown, moderately heavy silt loam, from 12 to 15 inches deep. This is underlain by a rather compact, mottled dark-brown or dark yellowish brown and drab, silty clay loam. At about 20 inches the subsoil changes to a mottled yellow, brown, and gray, moderately friable silty clay loam. The organic content of the surface soil is high. The compact nature and dark color of the subsurface layer is probably due to a concentration of clay particles and organic matter leached down from the surface soil. Dark brown to black iron concretions and stains are numerous in the lower subsoil. This series was also duplicated, one sample being taken in Leavenworth County, and a second was taken in Allen County. The general topography of the region in which this soil occurs is undulating to gently rolling or rolling.

Woodson silt loam has developed from parent material residual from gypsiferous shales. The surface soil is dark

Keith silt loam (Thomas County).
Colby Experiment Station.

Knox silt loam (Doniphan County).
East of Fanning.

Labette silt loam (Allen County).
West of Moran, west side, S.W.¼
Sec. 28, R20E, T24S.

Marshall silt loam (Doniphan-Brown County Line).
W. center of S.W. ¼
Sec. 30, T2S, R19E.

Neosho silt loam (Cherokee County).
¼ mile east of school house
District #90.

Shelby silt loam (Leavenworth County).
West of Jarbolo, S. center of S.E.¼
Sec. 6, T10S, R21E.

Summit silt loam (Leavenworth County).
1½ miles south of east Fairmount.

Summit silt loam (Allen County).
N.E. Carlyle, just east of S.W. corner
Sec. 24, R18E, T23S.

Woodson silt loam (Allen County)
East side and center
Sec. 5, R20E, T24S.

ANALYTICAL METHODS

The horizon samples were obtained from natural profiles. After air drying, representative samples were pulverized to pass a 2m.m. sieve, and stored. Soil thus prepared was used for pH determinations, but for all phos-to very dark grayish-brown to a depth ranging from 7 to 12 inches. The texture is somewhat finer than the surface layer and gray layer in Cherokee silt loam. This layer has a maximum thickness of nearly 20 inches, and it merges gradually into olive-green or yellow clay which contains various quantities of gypsum, both in powdered and crystal form, and lime concretions are present in many places.

Location of Soil Profiles

Cherokee silt loam (Cherokee County).
2½ miles north of Hallowell.

Cherokee silt loam (Labette County).
2 miles north of Parsons.

Crete silt loam (Jewell County).
1/8 mile E. of S.W. corner
Sec. 8, R7W, T3S.

Derby silt loam (Clay County).
4/10 mile E. of S.E. corner
Sec. 24, R2E, T7S.

Hays silt loam (Smith County).
Near Reamsville.

Idana silt loam (Clay County).
½ E. of S.W. corner
Sec. 4, R2E, T8S

Jewell silt loam (Jewell County).
4/10 mile W. of N.E. corner
Sec. 27, R7W, T5S.

Keith silt loam (Decatur County).
7 mile S. of Oberlin.

phorus determinations the 2m.m. samples were thoroughly mixed and small portions pulverized with a rubber tipped pestle until fine enough to pass a 100 mesh sieve.

To determine the absorption of phosphorus by the original soil, 10 gram samples from each horizonal subdivision were placed in a 200 ml. shaker bottle with 50mls. of phosphoric acid solution containing a known quantity of phosphorus. They were then placed on a shaker, agitated for 30 minutes and filtered. The phosphorus concentration of the filtrate was determined by the method of Truog (31). The writer assumes that the decrease in phosphorus content of the solution represents phosphorus fixed by the soil. No attempt was made to distinguish between fixation in easily soluble and in difficultly soluble form.

In order to prevent an extreme variation in the phosphorus concentration of the filtrate, standardized phosphoric acid solutions of four different concentrations were used - 19 p.p.m.; 33 p.p.m.; 57 p.p.m.; and 95 p.p.m. The pH value ranged from 2.7 for the solution containing 95 p.p.m. to 3.1 for that containing 19 p.p.m.

It was believed that if a sufficiently concentrated solution was used so that the filtrate in each case would contain an easily measurable amount of phosphorus, the quantity of phosphorus absorbed would better indicate the relative fixing power of the different soils. In practice, this involved trial and error to find the concentration needed.

Absorption was determined with certain samples after extraction of "available" phosphorus by the Truog procedure. For this purpose duplicate 2 gram samples of soil were extracted with 400mls. of Truog's extracting solution. It was found that 4 grams of soil were needed for the absorption determination in order to maintain the 1 to 5 soil solution ratio used in the original absorption determination and obtain sufficient filtrate for the colorimetric determination. Accordingly the duplicates were combined to give 4 grams of soil and 800 mls. of solution. This was necessary since the shaker available would not accomodate containers large enough to hold 800 mls. of solution. The soil and extract from the Truog procedure were separated by centrifuging. This means of separation made possible the obtaining of the 4 grams of soil, needed for the absorption determination, with negligible mechanical loss. 50 milliliters were removed from the supernatant extract obtained in this manner for available phosphorus determination. To the 750 mls. remaining, dilute NH_4OH was added to precipitate iron and aluminum and other substances precipitated by NH_4OH. Since the Truog extracting reagent is of low concentration, the amount of substances other than iron and aluminum removed from the soil should be relatively small. The precipitate was separated by filtration, ignited and determined as R_2O_3. The amount of R_2O_3 present in the aliquot part taken for available phosphorus determinution was calculated and accounted for in the final determination.

To the 4 grams of extracted soil were added 20 mls. of the standard phosphoric acid solution of the same concentration as was added to the corresponding sample in the original absorption determination. The remaining procedure was identical with that used for the original determination.

The pH value in all cases was determined by the quinhydrone electrode, using a 1:1 soil:water ratio.

All samples were duplicated in order to increase the accuracy of the determination.

EXPERIMENTAL RESULTS

The studies undertaken may be divided into several phases. Some of these phases are interrelated while others are more or less complete in themselves. For this reason the various phases are discussed under separate headings and some of the interrelationships are developed under the heading "Discussion."

On account of the desirability of making comparisons of the data for one profile with those for another and also the importance of comparing the data for the various horizons within each profile, it appeared logical to group all of the data in a body. All data obtained therefore are presented in table 1.

I. Phosphorus Absorption by the Original Soil

Absorption by the original soil in this study designates absorption before the available phosphorus had been extracted and will be referred to as original absorption.

In all soils studied, the B horizon showed greater absorption than the A horizon. This was more pronounced in the heavily leached soils than in the relatively unleached soils. The explanation for this undoubtedly lies in the fact that the B horizon is the zone of accumulation of iron and aluminum leached from the A horizon. With but two exceptions, the C horizon absorbed less than the B horizon. In the case of the Knox silt loam this difference was negligible. In the Labette silt loam, however, the difference was marked. The comparatively high absorption exhibited by the C horizon of the Labette profile, and by both the B and C horizon of the Summit (Allen County), Woodson and Shelby profiles is presumably due to a relatively large number of iron concretions in these horizons. In most instances, the difference in absorption between the B and C horizons was not marked. In all of the soils studied, original absorption by the A horizon increased with depth. It may be seen from a study of the tabulated data in table 1, that absorption in all profiles increased with depth to the B horizon where maximum absorption was exhibited. The B and C horizons of the more heavily leached soils absorbed from 2 to 5 times as much phosphorus as did the B and C horizons of the relatively unleached soils.

A striking example of the indirect influence of leaching on phosphorus absorption was revealed in comparing the original absorption of the Knox profile with that of the Hays profile. It was found that original absorption values throughout the two profiles were nearly equal. The Knox profile has developed in a region having an average annual precipitation of about 35 inches, while the Hays profile has developed under approximately 22 inches of annual rainfall. Equal absorption by the two profiles, therefore, appears inconsistent with other findings in this study, namely, that the profiles which had developed under the heaviest rainfall exhibited the highest absorption. When it is considered that the Knox profile studied was developed on a very rolling to very hilly topography, equality in absorption by the two profiles can be explained. Because of a hilly topography and consequently a greater run-off, leaching has not been as extensive and therefore less effective in developing a zone of iron and aluminum accumulation than would be true with equal rainfall on more level areas in the same environment. The hilly topography has apparently offset the difference of 13 inches in rainfall so that the Knox and the Hays profiles are comparable from the standpoint of the development of a zone of iron and aluminum accumulation. This is further evidenced by their comparable pH values.

II. "Available" Phosphorus

A study of the data in table 1, reveals that in the leached soils, "available" phosphorus in the first depth of the A horizon is relatively high as compared to the lower depths of the same horizon. This is explained by the high organic matter content in the first depth of the A horizon which possibly would supply an appreciable amount of available phosphorus. The high organic matter content would also tend to maintain a higher degree of base saturation in the first depth of the A horizon, as shown by the pH value in table 1. In all horizons low availability was associated with low pH values as revealed in figure 1. This is probably due to the lack of strong bases indicated by low pH values and a consequent increase in the activity of iron and aluminum in phosphorus fixation.

In the relatively leached soils low availability extended throughout the lower part of the profile, while in the relatively unleached soils available phosphorus tended to increase with depth, reaching a maximum in the C horizon.

No well defined relationship appears to exist between the R_2O_3 extracted by the Truog extracting solution and the

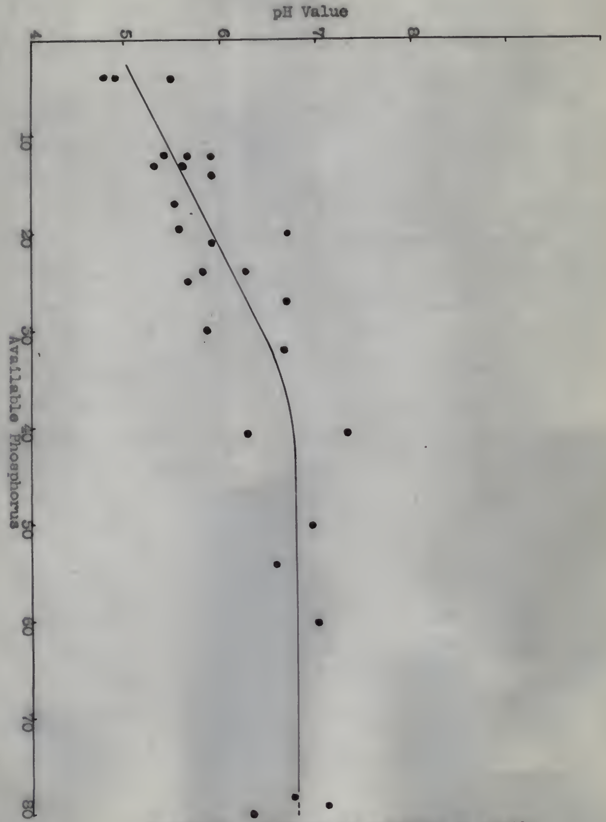

Figure 1. pH value in relation to available phosphorus. (A Horizon).

available phosphorus of the various horizons. However, in the relatively unleached profiles (Hays, Crete, and Knox), it was found that comparatively high "available" phosphorus was associated with relatively high amounts of R_2O_3 extracted.

Generally speaking lowest availability occurred in the B horizons. This is in agreement with the well known and widely recognized low availability of phosphorus in subsoils as indicated by plant growth. Since B horizons show high absorptive capacity and low availability of phosphorus, there is suggested the idea of using the absorptive capacity of the soil rather than the amount of "available" phosphorus extracted, as a measure of the soils need for phosphorus.

III. Phosphorus Absorbed After Extraction

In all cases the extraction of "available" phosphorus reduced the capacity of the soil to absorb phosphorus as shown in table 1. The percentage reduction was highest in the relatively unleached soils. In all of the soils studied the percentage reduction in the A horizon was greater than in either the B or C horizons.

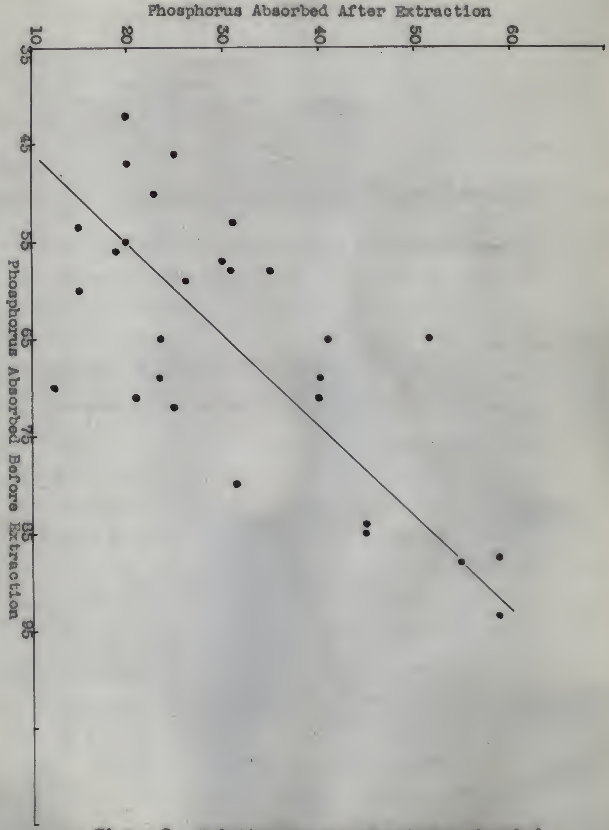

Figure 2. Relation between phosphorus absorbed before extraction and phosphorus absorbed after extraction. (A Horizon).

In the B and C horizons of the relatively leached soils, the percentage reduction varied inversely as the original absorption. The B and C horizons of the Summit (Allen County), Woodson, Shelby, and Labette profiles exhibited comparatively high absorption after extraction as shown in figure 3. It is apparent that the relatively high absorption in these horizons is due in large measure to factors other than extractable R_2O_3. Metzger (26) has shown that the B and C horizons of these profiles contain from 50 to 65 percent of particles of colloidal size. This very high content of colloids may offer an explanation of the behavior of these profiles. It may also be true that the extracting solution, which is .002 N with respect to H_2SO_4 and contained 3 grams of $(NH_4)_2SO_4$ per liter, was too weak to remove more than a portion of the abundant free iron from these horizons. Hence the absorption after extraction might be greater in proportion to the original absorption than in soils in which the iron was more completely removed by the extracting reagent.

It is of interest, however, to note that the reduction in absorptive capacity in these horizons compared rather favorably with other findings in this study. In figure 4,

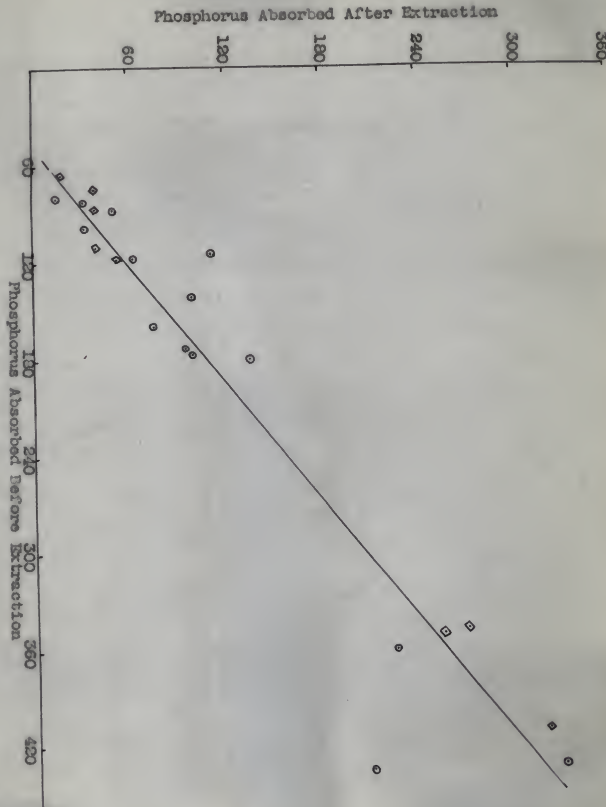

Figure 3. Relation between phosphorus absorbed before extraction and phosphorus absorbed after extraction. (● - B horison ▣ - C horizon).

there is indicated a general relationship between the R_2O_3 extracted and reduction in absorptive capacity.

The Crete, Hays, and Knox profiles, on the other hand, exhibit relatively low absorption after extraction indicating that in these profiles absorption is due primarily to to the extractable R_2O_3. This was somewhat surprising in view of the relatively weakly leached character of these profiles.

The first two depths in the Crete profile exhibited negative absorption after extraction. That is, a greater amount of phosphorus appeared in the filtrate obtained after treating the soil with the H_3PO_4 solution then there was before it came in contact with the soil. This is possibly explained by the weakly acid nature of the phosphoric solution, since its pH value was practically the same as that of the Truog extracting reagent. Negative absorption, may also be a case of a soil being unable to fix as much phosphorus as is contained in the water that is taken out of the role of a solvent by the soil. In such case the excess phosphorus increases the concentration of the remaining free solution, making it seem as if some of the phosphorus had actually been dissolved from the soil. This explanation is not adequate for the negative absorption exhibited by the first two depths of the Crete, however, because the soil was already saturated with water before the phosphorus solution was added.

IV. R_2O_3 Extracted

In general the reduction in apparent absorptive capacity (available phosphorus plus original absorption) varied directly as the R_2O_3 extracted. This was true of all horizons as shown in figure 4.

In the data for the A horizons there was some relationship between the R_2O_3 extracted and absorption by the original soil as shown in figure 6. This was not true of the B and C horizons, especially in the heavily leached soils.

It was found that the A horizon of the Crete profile exhibited a comparatively high apparent absorptive capacity, while the amount of extractable R_2O_3 was relatively low, indicating some fixation by soluble bases. In figure 7. line CD represents values for the A horizon of the Crete profile; line AB represents values for A horizons of other profiles studied.

In this study the greatest amount of extractable R_2O_3 was found in the B horizon of the Cherokee profile (Labette

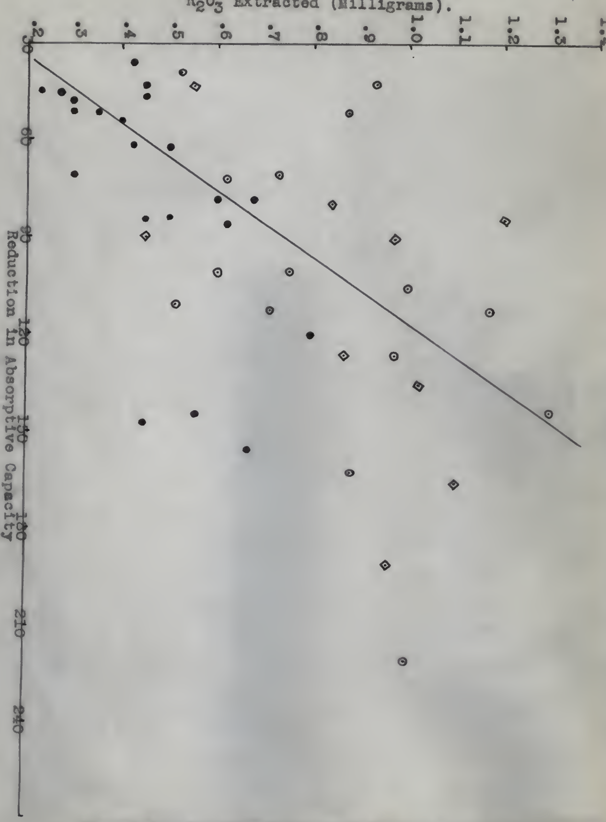

Figure 4. Relation between R_2O_3 extracted and reduction in absorptive capacity.
(● - A horizon ◉ - B horizon ◘ C horizon)

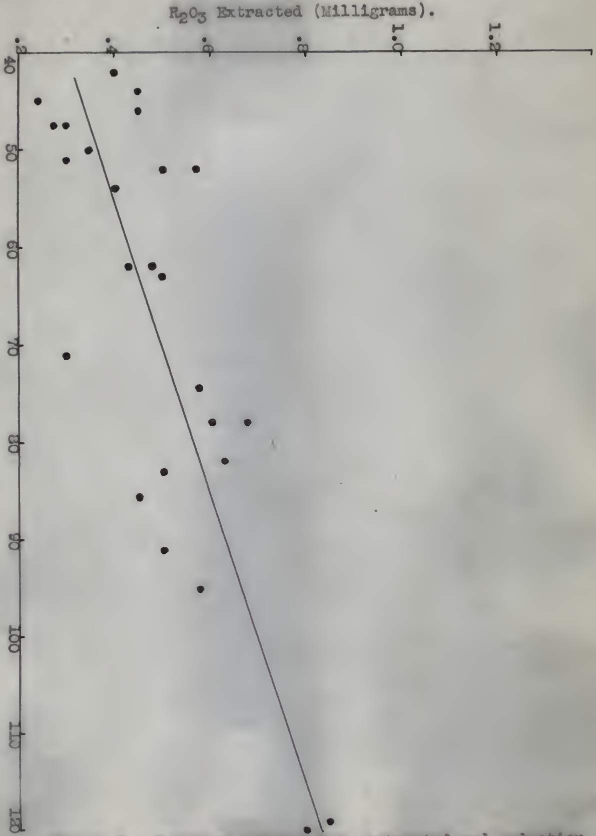

Figure 5. Relation between R_2O_3 extracted and reduction in absorptive capacity. (A horizon).

Table 1. Phosphorus Absorption of Various Soils As Influenced by Extractable R_2O_3, pH Value and the Nature of the Soil Profile.

Cherokee silt loam (Labette County)

Horizon and Depth Inches	Phos. absorbed by original soil (p.p.m.)*	Available Phosphorus (p.p.m.)	Apparent absorptive capacity** (p.p.m.)	Phos. absorbed after extraction (p.p.m.)	Reduction of absorptive capacity (p.p.m.)	% reduction in absorptive capacity.	R_2O_3 removed by extraction reagent. (mgs. per 100 grams of soil).	pH value
A, 0-4	47.5	14.6	62.1	20.0	42.1	67.3	50	5.91
A, 4-12	65.0	4.5	69.5	27.0	42.5	61.2	40	5.26
A, 12-18	80.6	4.0	84.6	32.5	52.1	61.6	50	4.97
A, 18-20	88.4	4.0	92.4	55.0	37.4	40.5	57	4.98
B, 20-23	179.4	4.0	183.4	97.5	85.9	46.9	120	5.12
B, 23-28	176.5	4.0	180.5	95.5	85.0	47.0	130	5.51
C, 34+	87.1	4.0	91.1	57.0	34.1	37.5	87	6.42

Cherokee silt loam (Cherokee County)

Horizon and Depth Inches	Phos. absorbed by original soil (p.p.m.)*	Available Phosphorus (p.p.m.)	Apparent absorptive capacity** (p.p.m.)	Phos. absorbed after extraction (p.p.m.)	Reduction of absorptive capacity (p.p.m.)	% reduction in absorptive capacity.	R_2O_3 removed by extraction reagent. (mgs. per 100 grams of soil).	pH value
A, 0-2	42.5	30.3	72.8	20.0	52.8	72.3	57	6.67
A, 2-7	53.0	7.5	60.5	32.5	28.0	46.3	57	5.35
A, 7-14	132.5	7.0	139.5	107.0	32.5	23.3	70	5.18
A, 14-18	143.7	10.0	153.7	107.0	46.0	30.4	105	5.08
B, 18+	153.7	5.0	158.7	127.5	31.0	20.0	122	5.45

* p.p.m. parts per million parts of air dry soil

** Apparent absorptive capacity available phosphorus plus phosphorus absorbed by original soil.

Table 1. Continued.

Crete silt loam

Horizon and Depth Inches	Phos. absorbed by original soil (p.p.m.)*	Available Phosphorus (p.p.m.)	Apparent absorptive capacity** (p.p.m.)	Phos. absorbed after extraction (p.p.m.)	Reduction of absorptive capacity (p.p.m.)	% reduction in absorptive capacity.	R_2O_3 removed by extraction reagent. (mgs. per 100 grams of soil).	pH value
A, 0-4	50.0	88.0	138.0	-10.0	148.0	107.2	45	7.09
A, 4-9	81.9	70.0	151.9	-15.0	146.9	111.4	50	6.96
A, 9-17	86.9	77.5	167.4	11.6	156.7	93.0	67	6.77
B,17-24	89.9	93.3	180.2	13.3	166.9	92.6	87	6.98
C,24+	66.2	155.0	221.0	18.3	202.7	91.7	97	7.67

Derby silt loam

Horizon and Depth Inches	Phos. absorbed by original soil (p.p.m.)*	Available Phosphorus (p.p.m.)	Apparent absorptive capacity** (p.p.m.)	Phos. absorbed after extraction (p.p.m.)	Reduction of absorptive capacity (p.p.m.)	% reduction in absorptive capacity.	R_2O_3 removed by extraction reagent. (mgs. per 100 grams of soil).	pH value
A, 0-3	46.2	24.0	70.2	25.0	45.2	74.3	22	6.59
A, 3-9	69.0	25.0	94.0	40.0	54.0	57.5	40	5.60
A, 9-17	146.2	12.5	158.7	75.0	83.5	52.5	50	5.55
B,17-27	160.0	13.6	173.6	75.0	98.6	56.8	60	5.65
C,27+	80.9	51.2	132.2	40.0	92.2	69.5	45	6.84

Hays silt loam

Horizon and Depth Inches	Phos. absorbed by original soil (p.p.m.)*	Available Phosphorus (p.p.m.)	Apparent absorptive capacity** (p.p.m.)	Phos. absorbed after extraction (p.p.m.)	Reduction of absorptive capacity (p.p.m.)	% reduction in absorptive capacity.	R_2O_3 removed by extraction reagent. (mgs. per 100 grams of soil).	pH value
1, 0-12	78.1	52.0	130.1	10.0	120.1	92.3	60	6.45
2,12-30	81.5	60.0	141.5	15.0	126.5	89.4	67	6.84
3,30-38	75.0	62.5	137.5	10.0	127.5	92.7	87	7.49

Table 1. Continued.

Idana silt loam

Horizon and Depth Inches	Phos. absorbed by original soil (p.p.m.)*	Available Phosphorus (p.p.m.)	Apparent absorptive capacity** (p.p.m.)	Phos. absorbed after extraction (p.p.m.)	Reduction of absorptive capacity (p.p.m.)	% reduction in absorptive capacity.	R_2O_3 removed by extraction reagent. (mgs. per 100 grams of soil).	pH value
A, 0-5	60.0	26.6	86.6	15.0	71.6	82.6	30	6.13
A, 5-15	63.7	13.5	77.2	15.0	62.2	80.5	42	5.91
A, 15-19	70.8	14.5	85.3	22.5	62.8	54.2	50	5.59
B, 19-29	87.8	32.0	119.8	61.7	58.1	48.5	62	6.72
C, 29+	80.8	23.3	104.1	55.0	59.0	57.1	50	7.84
			Jewell silt loam					
A, 0-3	55.0	60.0	115.0	20.0	95.0	82.7	57	7.09
A, 3-11	70.0	25.6	95.6	12.5	83.1	87.0	62	6.67
A, 11-14	76.9	27.5	104.4	12.5	91.9	88.0	50	6.21
B, 14-30	86.5	73.5	160.0	32.5	127.5	80.0	72	7.05
C, 30+	63.7	181.8	245.5	41.5	204.0	83.0	65	7.85
			Keith silt loam (Decatur County)					
1, 0-6	25.0	----	----	----	----	----	--	6.84
2, 6-22	52.5	----	----	----	----	----	--	6.82

Table 1. Continued.

Keith silt loam (Thomas County)

Horizon and Depth Inches	Phos. absorbed by original soil (p.p.m.)*	Available Phosphorus (p.p.m.)	Apparent absorptive capacity** (p.p.m.)	Phos. absorbed after extraction (p.p.m.)	Reduction of absorptive capacity (p.p.m.)	% reduction in absorptive capacity.	R_2O_3 removed by extraction reagent. (mgs. per 100 grams of soil).	pH value
1, 0-10	55.0	----	----	----	----	----	--	7.09
2,10-26	77.2	----	----	----	----	----	--	6.01
3,26+	72.5	----	----	----	----	----	--	6.72
				Knox silt loam				
A, 0-8	72.2	38.0	110.5	25.0	85.5	77.4	45	7.32
B, 8-24	75.0	60.0	135.0	23.5	91.5	82.6	52	6.65
C,24+	78.7	100.0	178.7	21.7	157.0	87.8	87	7.19
				Labette silt loam				
A, 0-2	71.2	19.0	90.2	40.0	50.2	55.6	35	5.58
A, 2-14	83.7	7.5	91.2	45.0	46.2	50.5	45	4.86
B,14-24	180.5	5.0	185.5	135.0	50.5	27.0	87	4.84
C,24+	454.6	4.0	458.6	375.0	83.6	18.1	112	4.90

Table 1. Continued

Marshall silt loam

Horizon and Depth Inches	Phos. absorbed by original soil (p.p.m.)*	Available Phosphorus (p.p.m.)	Apparent absorptive capacity** (p.p.m.)	Phos. absorbed after extraction (p.p.m.)	Reduction of absorptive capacity (p.p.m.)	%reduction in absorptive capacity	R_2O_3 removed by extraction reagent. (mgs. per 100 grams of soil).	pH value
A, 0-4	56.2	80.0	136.2	18.0	118.2	86.8	85	6.28
A, 4-14	69.6	32.0	101.6	27.5	74.1	73.0	57	6.72
B, 14-30	88.6	14.0	102.6	50.0	52.5	50.0	75	6.04
C, 30+	84.2	45.0	129.2	45.0	84.2	65.2	120	6.04
Neosho silt loam								
A, 0-2	50.0	14.3	64.3	23.5	40.8	63.5	47	5.89
A, 2-7	59.0	4.0	63.0	26.0	37.0	58.8	55	5.15
A, 7-14	112.2	4.0	116.2	76.5	39.5	34.2	102	5.03
B, 14+	162.5	5.0	167.5	73.5	94.0	56.2	120	5.00
Shelby silt loam								
A, 0-4	76.5	17.0	93.5	15.0	78.5	83.8	60	5.52
A, 4-7	80.9	12.5	93.4	15.0	78.4	92.5	67	5.42
B, 7-20	358.8	6.5	364.5	225.0	139.5	38.4	127	5.58
C, 20+	347.9	42.0	389.9	255.0	134.9	35.0	117	6.18

Table 1. Continued

Summit silt loam (Leavenworth County)

Horizon and Depth Inches	Phos. absorbed by original soil (p.p.m.)*	Available Phosphorus (p.p.m.)	Apparent absorptive capacity** (p.p.m.)	Phos. absorbed after extraction (p.p.m.)	Reduction of absorptive capacity (p.p.m.)	% reduction in absorptive capacity	R_2O_3 removed by extraction reagent. (mgs. per 100 grams of soil).	pH value
A, 0-5	57.5	24.0	81.5	30.0	51.5	63.2	30	6.15
A, 5-15	65.0	13.6	78.6	41.7	36.9	46.9	42	5.77
B,15-30	82.8	6.8	89.6	51.7	37.9	42.5	52	5.63
C,30+	86.5	4.0	90.5	50.0	40.5	44.7	55	6.64
				Summit silt loam (Allen County)				
A, 0-2	58.2	24.0	82.2	35.0	47.2	65.7	30	5.64
A, 2-13	85.0	4.0	89.0	45.0	44.0	49.4	45	5.59
B,13-28	434.0	4.5	438.5	332.5	106.0	24.1	102	5.58
C,28+	411.0	10.0	421.0	320.0	101.0	24.0	95	6.82
				Woodson silt loam				
A, 0-2	58.0	20.7	78.7	31.7	47.0	59.7	27	5.94
A, 2-9	65.0	7.5	72.5	45.0	27.0	38.1	40	4.82
B,12-26	436.0	4.0	440.0	288.5	231.5	35.3	107	4.96
C,26+	355.0	10.5	365.5	275.0	90.5	24.7	97	6.45

County). The gray layer of the same profile contained approximately one half as much easily extractable R_2O_3 as the layer just below. Likewise the original absorption and the apparent absorptive capacity of the gray layer were approximately one-half that of the underlying zone.

The gray layer in the Cherokee profile is the result of a perched water table. During wet seasons, the impervious nature of the claypan subsoil checks the downward movement of water and causes a temporary or perched water table in the layer immediately above it. Such a condition is conducive to reduction with the result that much of the ferric iron has been reduced. Being soluble in the ferrous state, the iron has moved to lower depths. The characteristic color of the gray layer is due to low iron content. This relatively low iron content is presumably the cause of the lower original absorptive capacity of the gray layer than the layer immediately below it.

DISCUSSION

It was thought that a relationship might exist between the phosphorus absorbed by the original soil and the R_2O_3 extracted. However, when plotted against each other as

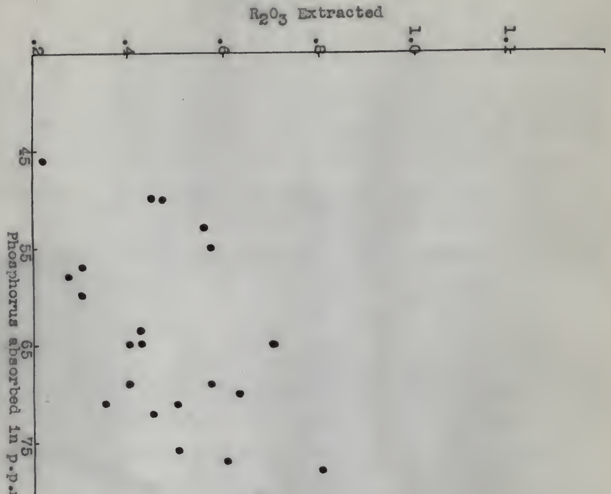

Figure 6. R_2O_3 Extracted in relation to phosphorus absorbed by original soil. (A horizon).

shown in figure 6, a correlation was revealed in the A horizon, but practically no relationship existed in the B and C horizons. Values for the B and C horizons were plotted, but because of no apparent relationship are not presented in this study. The closer relationship in the A horizon is possibly due to a comparatively higher degree of saturation of the extractable R_2O_3 with phosphorus.

Reasoning that the amount of available phosphorus should be a measure of the degree of saturation of the extractable R_2O_3, it was believed that by adding the available phosphorus to that absorbed by the original soil, a measure of its absorptive capacity would be obtained. The values so obtained were designated apparent absorptive capacity. These values were plotted against the R_2O_3 extracted and a scatter diagram is shown in figure 8. It will be seen that values for the B and C horizons of the Summit (Allen County), Woodson, Shelby, and Labette profiles again tend to isolate themselves, as shown by the plotted points at the right hand side of the figure. As was previously stated extractable R_2O_3 is obviously not the dominant factor in phosphorus absorption in the above mentioned horizons of these profiles.

The apparent absorptive capacity was plotted against

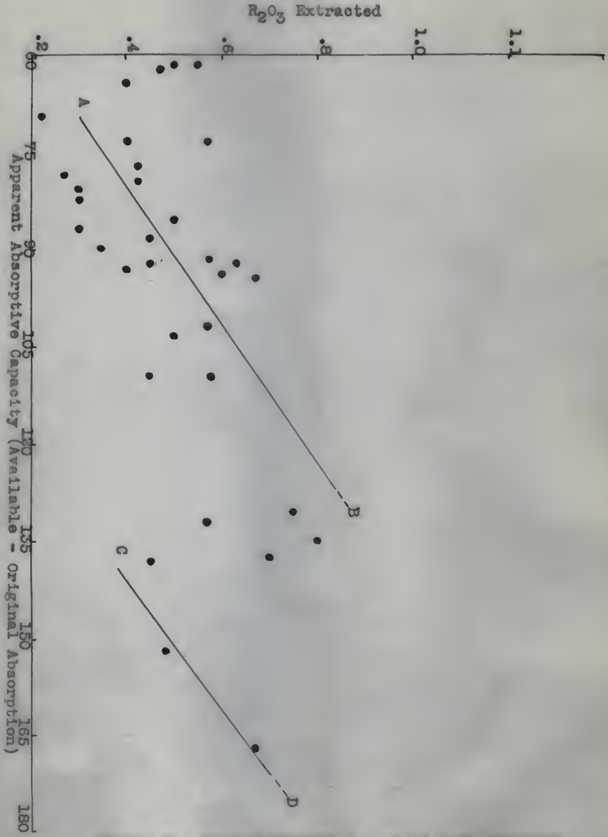

Figure 7. R_2O_3 extracted in relation to apparent absorptive capacity. (A horizon).

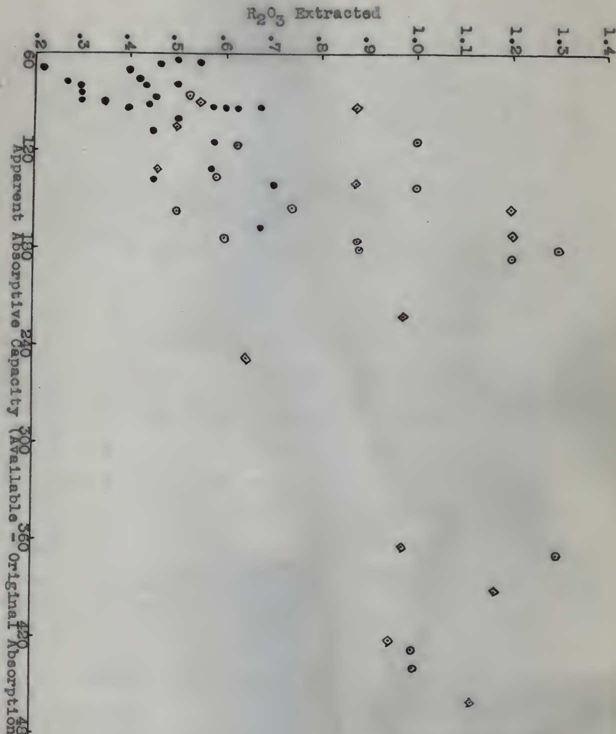

Figure 8. Scatter showing relation between R_2O_3 extracted and apparent absorptive capacity. (● - A horizon, ⊙ - B horizon, ◈ - C horizon).

reduction in absorptive capacity brought about by extraction, and a relationship was found as shown for the A horizons in figure 9, and the B and C horizons in figure 10. In using a larger scale it was necessary to plot the values for the A horizons separately from those for the B and C horizons in several of the relationships studied.

The data in table 1, indicate that the lower the "available" phosphorus the higher the original absorption. This was more noticeable in the B and C horizons than in the A horizon. Figure 2 shows the relation in the A horizons between phosphorus absorbed before extraction and phosphorus absorbed after extraction. Figure 3 shows the same relationship for the B and C horizons. A correlation is revealed in both figures.

In evaluating a study of phosphorus fixation by virgin profiles it might seem questionable to study the B horizon. However, due to the loss of a considerable portion of the A horizon through cultivation and erosion the B horizon frequently appears at the surface in cultivated areas. Also deep rooted crops such as alfalfa and sweet clover utilize nutrients from the B horizons of even non-eroded soils. The low availability of phosphorus in B horizons emphasizes the importance of erosion control since loss of the topsoil involves loss of most of the soils available phosphorus.

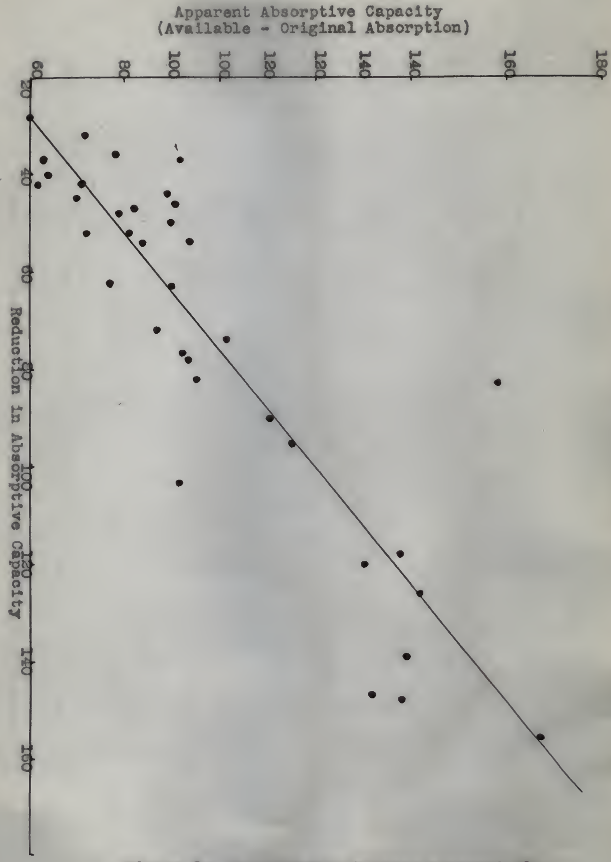

Figure 9. Relationship between apparent absorptive capacity and reduction in absorptive capacity. (A horizon).

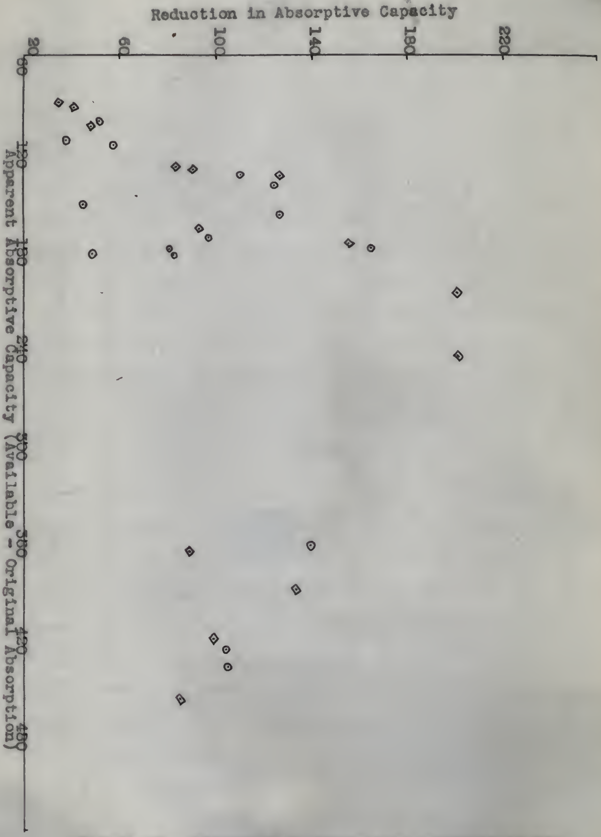

Figure 10. Reduction in absorptive capacity in relation to apparent absorptive capacity. (⊙ - B horizon, ◈ - C horizon).

The phosphorus status of the subsoil therefore becomes of some significance. Thus the properties and behavior of the B horizon with respect to phosphorus absorption are of immediate concern. Data here presented reveals that B horizons of the relatively leached soils are generally deficient in "available" phosphorus, and that low availability is usually associated with a high absorptive capacity. Therefore from a practical point of view not only is the amount of "available" phosphorus important, but also the degree to which the constituents capable of absorbing phosphorus are saturated by this element.

SUMMARY

A study has been made of the relative fixing capacity of several horizons of each of a number of soil types. An attempt has been made to determine what relationship, if any, exists between the easily extractable iron and aluminum and, (a) the easily extractable phosphorus, and (b) the phosphorus fixing capacity. This was done by determining the absorptive capacity of the soil in its original condition and again determining the absorptive capacity after the available phosphorus had been extracted by the Truog procedure.

Representative profiles from each of the Prairie, Chernozem and Chestnut soils areas were studied.

The results of the study of phosphorus absorption by the original soil indicate striking differences between leached and relatively unleached profiles. The B and C horizons of the more heavily leached soils absorbed from 2 to 5 times as much phosphorus as did the B and C horizons of the relatively unleached soils. In all cases the B horizon showed greater absorption than the A horizon. With but two exceptions, the C horizon absorbed less than the B. Generally speaking the difference in absorption between the B and C horizons was not marked.

The higher the "available" phosphorus the lower the absorption by the original soil. Extraction of "available" phosphorus reduced the capacity of the soil to absorb phosphorus. The percentage reduction in absorption after extraction of "available" phosphorus was highest in the relatively unleached soils. The percentage reduction in the A horizons was greater than in either the B or C horizons.

In all horizons the reduction in apparent absorptive capacity resulting from extraction of the soil by the Truog reagent varied directly as the R_2O_3 extracted (substances precipitated by NH_4OH).

In the data for the A horizons there was some relationship between the R_2O_3 extracted and the absorption by the original soil. This was not true of the B and C horizons, especially in the heavily leached soils.

A relationship existed between the apparent absorptive capacity (available phosphorus plus original absorption) and the reduction in absorption resulting from extraction.

Generally speaking lowest availability occurred in the B horizons. In the unleached profiles, high "available" phosphorus was associated with relatively high amounts of extractable R_2O_3. In the relatively leached soils low availability extended throughout the lower part of the profile while in the relatively unleached soils available phosphorus tended to increase with depth, reaching a maximum in the C horizon. Low availability was associated with low pH values.

ACKNOWLEDGMENT

To Dr. W. H. Metzger, his major instructor, and under whose direction this study was made, the author wishes to express sincere appreciation for constant interest and valuable suggestions.

LITERATURE CITED

(1) Benne, E. J., Perkins, A. T., and King, H. H.
The effect of calcium ions and reaction upon the solubility of phosphorus. Soil Sci. 42: 29-38. 1936.

(2) Bradfield, R., Scarseth, G., and Steele, J. G.
Factors affecting the retention of phosphates by clays. Transactions of the Third International Congress of Soil Science. Oxford England. Vol. 1. 74-75. 1935.

(3) Brown, L. A.
A study of phosphorus penetration and availability in soils. Soil Sci. 39: 277-287. 1935.

(4) Cook, R. L.
Divergent influence of degree of base saturation of soils on the availability of native, soluble and rock phosphate. Jour. Amer. Soc. Agron. 27: 297-311. 1935.

(5) Craig, N.
Some properties of the sugar cane soils of Mauritius. Mauritius Dept. Agr. Sugarcane Res. Bul. 4: 9. 1934.

(6) Davis, L. E.
Sorption of phosphates by non-calcareous Hawaiian soils. Soil Sci. 40: 129-158. 1935.

(7) de Vries, O. and Hetterschy, C. W. G.
Mobility of phosphoric acid in the soil. Bodenkunde u. Pflanzenernahr. 2: 178-186. Review in Chemical Abstracts. Vol. 31. No. 11. 1937.
(original not seen)

(8) Doughty, J. L.
Phosphate fixation in soils particularly as influenced by organic matter. Soil Sci. 40: 191-202. 1935.

(9) Doughty, J. L.
Fixation of phosphates by peat soil. Soil Sci. 29: 23-35. 1930.

(10) Ford, M. C.
The nature of phosphate fixation in soils. Jour. Amer. Soc. Agron. 25: 134-144. 1933.

(11) Gile, P. L.
The effect of different colloidal soil materials on the efficiency of superphosphate. U. S. Dept. Agr. Tech. Bul. 371. 1933.

(12) Hance, F. E.
Phosphate fixation in Hawaiian soils. Hawaii Planters' Rec. 37: 182-196. 1933.

(13) Heck, A. F.
Phosphate fixation and penetration in soils. Soil Sci. 37: 343-355. 1934.

(14) Heck, A. F.
Availability and fixation of phosphorus in Hawaiian soils. Jour. Amer. Soc. Agron. 27: 874-884. 1935.

(15) Heck, A. F., and Truog, E.
Phosphate Fixation. Abstract of papers presented at 24th annual meeting. Amer. Soc. Agron. p. 29. 1931.

(16) Heck, A. F.
Effect of the degree of base saturation of a soil on its capacity to fix phosphorus in difficulty available forms. Soil Sci. 38: 463-470. 1934.

(17) Hester, J. B.
The influence of phosphate fertilization upon the amphoteric properties of coastal plain soils. Jour. Amer. Soc. Agron. 29: 10-16. 1937.

(18) Hibbard, P. L.
Factors influencing phosphate fixation in soils. Soil Sci. 39: 337-358. 1935.

(19) Joffe, Jacob S.
Pedology. Rutgers University Press. New Brunswick, New Jersey. p. 372-375. 1936.

(20) McGeorge, W. T., Buehrer, T. F., and Breazeale, J. F.
Phosphate availability in calcareous soils: A function of carbon dioxide and pH. Jour. Amer. Soc. Agron. 27: 330-335. 1935.

(21) McGeorge, W. T., and Breazeale, J. F.
Studies on iron, aluminum and organic phosphates and phosphate fixation in calcareous soils. Ariz. Sta. Tech. Bul. 40. 1932.

(22) McGeorge, W. T., and Breazeale, J. F.
Phosphate solubility studies in some unproductive calcareous soils. Ariz. Sta. Bul. 35. 1931.

(23) Mattson, S.
The laws of soil colloidal behavior: V. Ion absorption and exchange. Soil Sci. 31: 311-331. 1931.

(24) Mattson, S.
The laws of soil colloidal behavior: III. Isoelectric precipitation. Soil Sci. 30: 459-495. 1930.

(25) Mattson, S.
Anionic and cationic absorption by soil colloidal materials of varying SiO_2/Al_2O_3 plus Fe_2O_3 ratio. Proc. First Int. Cong. Soil Sci. Comm. II, 2: 199-211. 1927.

(26) Metzger, W. H.
Unpublished data of the Kansas Agr. Exp. Sta. 1935.

(27) Meyer, A. H.
Phosphate fixing compounds in the soil. Soil Sci. 71: 467. 1930.

(28) Naftel, James A.
Soil liming investigations: II. The influence of lime on the sorption and distribution of phosphorus in aqueous and soil colloidal systems. Jour. Amer. Soc. Agron. 28: 740-752. 1936.

(29) Odyusky, W.
Solubility and distribution of phosphorus in Alberta soils. Sci. Agr. 12: 652-664. 1936.

(30) Pugh, A. J.
Laws of soil colloidal behavior: III. Colloidal phosphates. Soil Sci. 38: 315-334.

(31) Perkins, Alfred T., King, H. H., and Benne, E. J.
Effect of exchangeable base and soil treatments on phosphorus solubility. Soil Sci. 34: 385-392. 1932.

(32) Scarseth, G. D., and Tidmore, J. W.
The fixation of phosphates by soil colloids. Jour. Amer. Soc. Agron. 26: 138-151. 1934.

(33) Scarseth, G. D.
The mechanism of phosphate retention by natural alumino-silicate colloids. Jour. Amer. Soc. Agron. 27: 596-616. 1935.

(34) Snider, H. J.
The solubility of phosphorus in soils from some Illinois experimental fields. Soil Sci. 38: 471-476. 1934.

(35) Teakle, L. J. H.
Phosphate in the soil solution as affected by reaction and cation concentration. Soil Sci. 25: 143-162. 1928.

(36) Teakle, L. J. H.
Measuring absorbed phosphates. Science 73: 215-216. 1931.

(37) Thomas, Walter
The effect of colloidal silica on the absorption of phosphoric acid by plants. Science. 71: 422-423. 1930.

(38) Toth, S. J.
Anion adsorption by soil colloids in relation to changes in free iron oxides. Soil Sci. 44: 299-314. 1937.

(39) Truog, E.
The utilization of phosphates by agricultural crops, including a new theory regarding the feeding power of plants. Wis. Agr. Exp. Sta. Res. Bul. 41. 1916.

(40) Truog, E.
The determination of the readily available phosphorus of soils. Jour. Amer. Soc. Agron. 22: 874-882. 1930.

(41) Truog, E., and Ford, M. C.
New science for an old art. Wis. Agr. Exp. Sta. Bul. 410: 6-8. 1930.

(42) Tyulin, A. F.
Availability of soil phosphates for the plant from the viewpoint of colloidal chemistry. Soil Sci. 42: 291-299. 1936.

KANSAS STATE COLLEGE LIBRARIES